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METHODOLOGY FOR EVALUATING
NAVAL SHIPYARDS
Phase I - Model Feasibility

Task 72-8

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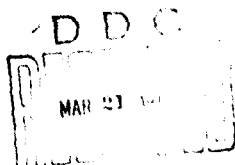


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SUMMARY

This report describes the work done in Phase I of LMI Task 72-8, Methodology for Evaluating Naval Shipyards. The overall objective of the study task was to develop a methodology for evaluating the relative utility of Naval shipyards in terms of cost and effectiveness. Phase I was a review of existing models and data, and selection of a model. Phase II was to be full-scale development and testing of the selected model. The conclusion of Phase I is that no model can be found which will satisfy the requirement. For this reason it is recommended that Phase II of the study be cancelled.

Four possible models were investigated. The first two, a scheduling-cost model and a linear programming model were rejected because an essential element, a measure of shipyard productivity, is not available. LMI does not believe the construction of a measure of productivity for detailed models is practicable for several reasons: 1) the nature of overhaul and repair work, that is, it is large and complex, and few jobs recur regularly and when they do work content varies widely, 2) the many constraints on shipyard operation, and 3) the differences among the shipyards themselves.

The third and fourth models, total cost comparison and fixed cost analysis, assume invariant productivity. The total cost model was found to discriminate inadequately between costs of new construction in private and Naval shipyards. The difficulty in finding comparable work packages in overhaul and repair work, the primary mission of Naval shipyards, suggests that that model would be even less useful.

The fixed cost analysis assumes that there are fixed costs of operating a shipyard that would be avoided by closing a yard. However, LMI can find little to support that assumption. There is no clear evidence that fixed costs are large enough to substantially offset the costs of closing a yard. This conclusion was supported by a review of the actual costs incurred in the closing of the New York Naval Shipyard.

I. INTRODUCTION

A. THE STUDY

This study, "Methodology for Evaluating Naval Shipyards," was requested by the Chief of Naval Operations.¹ It is aimed at the development of a model, or set of models, to be used to evaluate the relative utility of Naval shipyards, and to display the effect of changing numbers and capacities of shipyards.

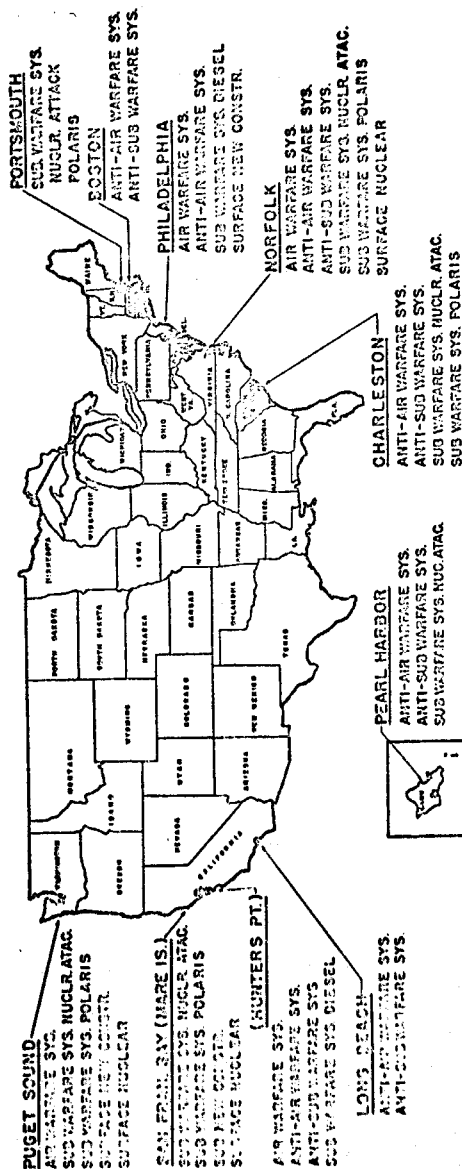
The study was to be conducted in two phases. Phase I includes the identification of categories of models, the assessment of the existing data base together with recommendations for improvement and, finally, selection of the most promising model. Phase II consists of the development and testing of the model selected in Phase I. This report describes the work done in Phase I.

B. BACKGROUND

There are ten Naval shipyards, located as shown in Figure 1, five on the Atlantic Coast, four on the Pacific Coast, and one in Hawaii. In addition there are 26 major private shipyards and a number of smaller private shipyards which do contract work for the Navy.

¹LMI Task 72-8. See Appendix A for a copy of the Task Order.

FIGURE 1
U.S. NAVAL SHIPYARD CAPABILITIES



The mission of the Naval shipyards is to service the fleet. The Naval shipyard's primary role is overhaul and repair of most of the Navy's combatant ships. The private shipyards handle almost all new construction work and perform overhaul and repair of some of the Navy's noncombatant ships. Also, private shipyards do overhaul and repair of some nuclear combatant ships.

Over the past three years the active fleet (both combatant and noncombatant) has been reduced from 935 to about 650 ships. As the size of the fleet has declined, the overhaul and repair workload also has declined. There is pressure from private industry for a proportionately larger share of this smaller workload to be placed in private shipyards. On the other hand, the retiring of many old noncombatant ships has reduced the kind of repair work which the Navy traditionally has placed with private yards.

Naval shipyard organizational structures and accounting procedures are similar from yard to yard.^{1,2} The Naval shipyards operate under the Navy Industrial Fund. Repair and overhaul work is paid for by fleet elements, while other work is reimbursed by the Systems Commands or other customers. Other work includes ship alterations and non-shipwork (industrial jobs performed for other Naval shipyards or other government activities).

¹Standard Naval Shipyard Organization Manual, NAVSHIPSINST 5450.14C, Department of the Navy, Naval Ship Systems Command, Washington, D. C., 1 June 1971.

²Navy Industrial Fund Handbook for Naval Shipyards, NAVEXOS P-1242.

The decrease in repair and overhaul work brought on by the reduction in fleet size and the continuing emphasis on placing new construction with private yards, has caused the Naval shipyard work force to decline. Employment in the Navy yards is about 73,000,¹ down from 94,000 at the end of 1967. Figure 2 shows the actual employment 1961-1971, and the work force predicted to be required in the shipyards through 1980.² The predicted continuing decline in the work force requirement was one of the factors that triggered the search for a model.

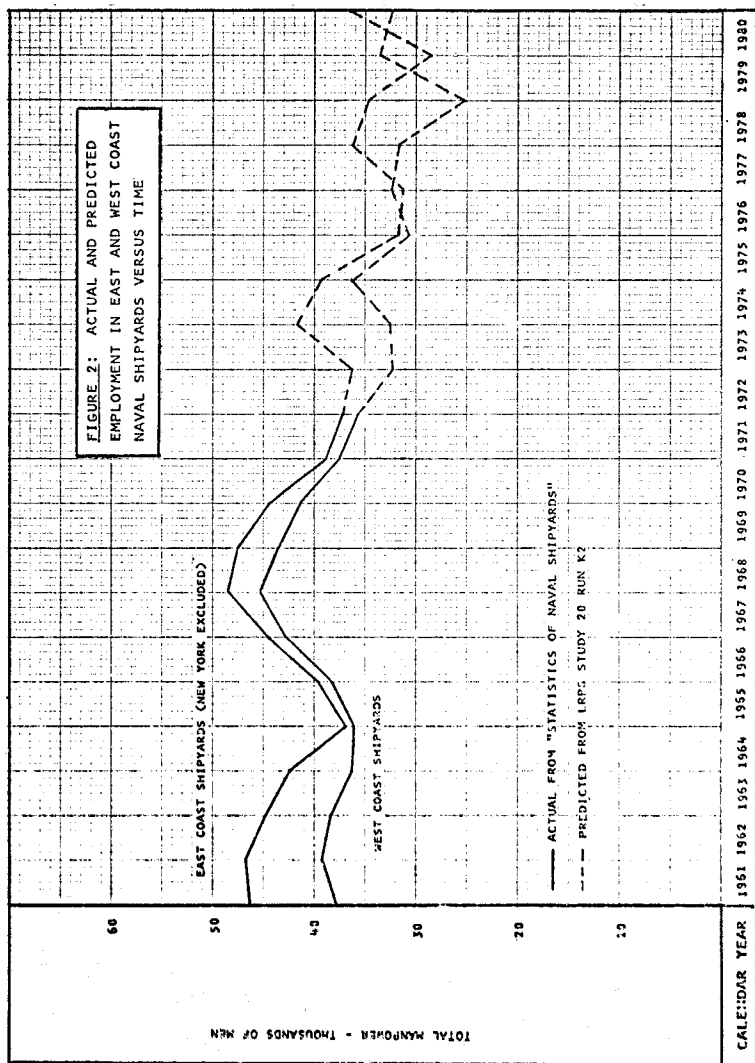
C. METHOD

The procedure adopted for this study was to (1) perform a literature search, (2) examine previous work in the subject area, (3) investigate Naval shipyard reports for data useful in the analysis, (4) visit members of the Naval Ship Systems Command to acquire background on the methods and procedures used for shipyard management, including ship scheduling, and (5) obtain corresponding scheduling and operating information from fleet commands and shipyards.

After examining the problem on this basis, we turned our attention to investigating types of models which might be useful in describing shipyard cost and performance, and to defining characteristics of the data required to support those models.

¹As of 30 November 1971.

²The prediction is obtained through use of the Long Range Planning System (LRPS), a Naval Ship Systems Command computerized planning model. The fluctuations in the prediction are inherent in the model, in that it searches for a feasible schedule rather than a smooth one. The LRPS prediction is the Navy's best estimate of its shipyard labor needs; however, there is no provision for uncertainty in the estimate. LRPS is discussed in more detail on page 12.



II. ANALYSIS

A. INTRODUCTION

The objective of this task was to obtain a model which would make it possible to evaluate the utility of Naval shipyards. The model was to show the effect of changing the numbers and capacities of the shipyards.

An ideal model would incorporate all of the factors affecting shipyard cost and performance, considering such variables as:

- The number and kinds of ships in the fleet.
- Operational requirements of the fleet and resulting schedules for shipyard availabilities.¹
- The characteristics of shipyard facilities and work forces.
- The management goals or performance targets for operating the yards.
- The distribution of work between Naval and private shipyards.
- The constraints of fleet policies, such as home-porting.

The essential expression of differences among the yards would be in terms of a measure of efficiency. The efficiency of a

¹An availability is an assignment of a ship to a repair activity for accomplishment of specific items of work.

yard is a function of productivity of the work force, workload scheduling, shipyard characteristics, and management practice; they are essential elements of a model for Naval shipyard analysis.

1. Productivity¹

Measures of labor productivity for new ship construction may be developed on the assumption that end product quality and workmanship on newly completed ships are the same. Then the productivity measure is some measure of the labor, resources, and material required to produce a completed ship--a ship that did not exist before. However, even in new construction, past efforts to develop productivity measures have obtained uncertain results except for identical ships. Appendix C is a comparison of two typical studies which addressed the problem of measurement of shipbuilding productivity on a national level. The results were conflicting.

Measures of the productivity of ship overhaul and repair, the primary mission of Naval shipyards, are more difficult to develop than for new construction. No valid output comparisons among yards can be made. Incoming ships are not in equally deteriorated condition, and ships leaving a shipyard are not in equally good condition. An earlier study searched for material condition measures for ships and concluded that no measure of ship condition is available.² If there were such a measure, it might be used as a measure of shipyard overhaul and

¹For purposes of this study, productivity is defined as the amount of work accomplished per man-hour of labor expended.

²LMI Task 69-16, "Study of the Navy Ship Maintenance Program," Vols. I and II, March 1971.

repair productivity by determining the degree of improvement in a ship's material condition during an overhaul.

It can be argued that productivity would be measurable if we had a large number of similar availabilities on similar ships or ship types, thereby making it possible to evaluate the effect of variables not under yard control. However, the number of ships of each ship type is small, availabilities occur infrequently and the work packages are dissimilar. Repair work packages are too varied in composition and the occurrence of similar packages is too infrequent to have resulted in the establishment of standards of comparison.

2. Scheduling

Efficient use of shipyard manpower depends in part on leveling of workload in order to avoid "peaks" and "valleys." Manpower in Naval shipyards is under Civil Service. Shipyard work forces cannot be readily adjusted to short-term variations in workload.

Since yards exist to service the fleet, the scheduling of ships for yard availabilities is based primarily on fleet operational requirements. Availabilities are dictated largely by operational commitments of fleet commanders. Some workload leveling has been done through scheduling conferences with the fleet commanders; however, with the declining number of ships, there is less opportunity to reschedule availabilities to make more efficient use of the shipyards. Each shipyard tries to level its workload through internal rescheduling within the lengths of availabilities, and by obtaining outside, less rigidly scheduled work to fill the valleys.

Of course, no one can predict the necessity for emergency repairs, nor can one foresee the occurrence of isolated catastrophes, such as those which struck the FORRESTAL and the ENTERPRISE. Yet, such events substantially disrupt a shipyard's workload schedule immediately, and the effect of the disruption may linger for years.

While work leveling of a shipyard is important to its efficiency, there are many external constraints that make it difficult for a yard to level its workload. For instance, new construction of ships now is being assigned almost exclusively to private yards, whereas, in the past, a relatively low level of new construction in a Naval shipyard provided some much needed flexibility in scheduling the work force. Also, the shipyards are more constrained by policy than in the past in seeking out non-shipwork. Both new construction and non-shipwork have served as "flywheels" in smoothing shipyard workload.

Even with the best smoothing some peaks and valleys in workload requirements will exist. In order to select an efficient manpower level to meet the workload requirements, it is necessary to know the relative value of peak and valley man-hours. In a specific overhaul, which is not describable in terms of average workloads, it is not possible to determine whether man-hours were expended on a repair requirement or were expended only because the manpower was there. This inability to analyze the value of a man-hour extends into overtime work. For this reason, historical data cannot be used to establish the relative value of peak and valley man-hours. Again, a productivity measure would allow such values to be established, and realistic comparison could be made of schedules containing peaks and valleys.

3. Shipyard Characteristics

Comparison of similar operations among the shipyards is made even more difficult because of differences in shipyards. The organization (design, layout, staffing, etc.) of a shipyard is as dependent upon its output mix as is any manufacturing operation. This fact is reflected in yard facilities: width, length, and depth of drydocks; crane types and capacities; pier space; shops and shop equipment; and material handling equipment.

Shipyard differences are also reflected in the kind and number of personnel required. New construction yards need highly organized groups of specialists, skilled at assembly of large sections and at translating drawings into hardware. Repair yards need groups of highly skilled generalists capable of handling many facets of a repair job without much in the way of layouts, drawings, and process specifications.

Furthermore, the Naval shipyards have become specialized as a matter of deliberate design. In Figure 1 (page 2), the functional specialization of each of the yards is shown. Some yards have nuclear propulsion system overhaul capability and some do not. Nuclear work requires different brazing, welding, machining, material handling and, perhaps most significant, quality assurance techniques than does ordinary ship repair. Similar comments apply to the skills involved in repair of electronics for anti-war warfare and antisubmarine warfare weapons systems. These specialization differences increase the difficulty of comparison of overhaul and repair operations and their costs.

4. Management Practice

Another factor in the Naval shipyards is their management practices. An industrial organization should have freedom

to allocate its resources to enhance its efficiency. However, a number of limitations exist for Naval shipyards, including:

- Civil Service manpower restrictions (hiring and firing procedures).
- Navy Department imposed manpower ceilings/floors.
- Modernization budget limitations (new capital investment).
- NAVSHIPSYSCOM management attention to application of resources (overhead ratios, maintenance cost ratios, training cost ratios, and overtime amounts).
- Imposed shipwork requirements.
- Imposed support requirements (tenant activities).

It is not necessary for purposes of this report to consider those factors in greater detail, but a model should recognize their importance.

B. MODEL ANALYSIS

Based upon a preliminary review, four types of models were identified that had some promise of meeting the study objective. The four types may be described as:

- Simulation
- Linear Programing
- Total Cost Comparison
- Fixed Cost Comparison

1. Simulation

The simulation model considered was a combination of a shipyard workload algorithm and a costing algorithm. The model assumed that operational and overhaul policy constraints were inviolate and that shipyard costs would be optimized within those limitations.

The best workload scheduling algorithm for a simulation model would be one that optimizes allocation of resources. Such models exist.¹ They cannot be used in examination of the shipyard utility problem because they require freedom to shift overhaul start dates and to increase the length of overhauls, i.e., length of shipyard availabilities. In that situation it was decided to attempt to use the Long Range Planning System (LRPS) as a workload scheduling algorithm even though it was recognized that it does not optimize resource allocation.

The LRPS seeks a feasible scheduling of ships into shipyards over a ten-year period. In doing so, the model considers the following constraints: workload requirements for each ship, operating-repair cycles, homeport policies, shipyard specialization capabilities, drydocking facilities, manpower and skill bounds, and fleet-assigned ship repair priorities. Since schedules are fixed, the model may encounter conditions where shipyard capacities are overloaded. Relaxation of schedule constraints is required, and through manual intervention specific overhauls are shifted until a feasible schedule is achieved.

¹Optimization scheduling models examined during this study were, 1) Control Data Corporation, "PPS IV Project Planning System," and 2) those contained in: Thompson, G. L., "Current Approaches to Solving Workload Scheduling, Prediction, Distribution, and Smoothing Problems," Carnegie Institute of Technology, April 1965.

It was planned to apply the LRPS to each of several alternative yard combinations, and through application of a cost algorithm, cost out the results. Costs to be included in the costing algorithm are given in Table 1. The first LRPS run would be for the current yard complex and would be the standard. Subsequent runs would be with selected yards deleted, so that the value of each such yard could be determined from a comparison of the corresponding costs with the standard.

Table 1

Cost Data Required for Scheduling Model

Cost/Saving	Data Required	Notes
Transfer Capability	Requires determination of facilities required, post closing. (Drydock, crane, pier space, other)	Dependent upon scheduling and yard specialization designation.
NSY Facilities		
Moving Costs		
Replacement Costs		
NSY Personnel	Requires determination of total manpower required, and of percentages that will transfer and be needed or of replacement and termination percentages.	Dependent upon scheduling and estimate of personnel action percentages.
Transfer		
Travel Expense		
Moving Expense		
Loss/Replacement		
Severance Pay		
Early Retirement		
Recruiting		
Training		
Efficiency	Productivity loss.	Few data available.
On-the-Job Training		
Lowered Skill		
Morale		
Rescheduling	Cost of "peak" and "valley" man-hour	Dependent upon scheduling and micro-leveling done in yard plus cost estimates.
Peak/Valley Shift		
Transit Costs Difference	Requires listing of ships and homeport to availability yard distances.	Dependent upon scheduling, and ship homeport preference designation.
Steaming		
Lost Availability		
Homeport Separation Difference	Requires listing of ships and homeport to availability yard distances.	Dependent upon scheduling and ship homeport preference designation.
Crew Travel		
Relocation		
Morale	Comparative reenlistment rates.	Few data available.
Shipyard Preplanning		

The closing of a shipyard implies that a number of decisions must be made, including the date of closing, a new homeport-shipyard preference list and selection of yards to which to transfer specialized skills. The result is that the generation of alternative shipyard workload schedules is not a deterministic process, but one with very large numbers of alternatives, each having a differing variation in the peaks and valleys of workload attributed to the shipyards. It is because it is not deterministic that LRPS fails. Its shortcomings became evident following a detailed examination of the standard run (without the cost algorithm applied). The projected manpower requirements showed wide fluctuations for the immediate fiscal year and wider and wider fluctuations for succeeding years. Normally, such fluctuations are removed manually by analysts and operating personnel based on updated information as the overhaul period is approached. However, it is not practical to simulate such situations far enough into the future to cover the period when the impact of the hypothetical closing of a yard can be determined. While LRPS appears to be a good tool for long-range planning, it is not suitable for intra-shipyard analysis of schedules.

Assuming that the difficulty in simulating the long-term future situation could be overcome, other obstacles remain. First, in order to assign costs to the variation in workload, a manpower level must be chosen. The productivity of a peak man-hour compared with a valley man-hour must be known in order to set the manpower level. Productivity data do not exist that would enable the manpower level to be set to minimize costs. Second, even though workload might be smoothed in each yard, the absence of productivity data effectively makes it impossible to determine productivity among the yards. Third, estimates of the other

cost factors, listed in Table 1, do not appear to be available to the precision required.

In view of the foregoing, it is concluded that no objective evaluation could emerge from a simulation of the shipyard complex.

2. Linear Programing

Linear programing is simulation using mathematical equations to represent physical events, and usually assumes continuous flow. It requires that the relationship between cost and output be known. An illustration of the technique can be found in a report by the Institute for Defense Analyses (IDA) in 1969.¹ That linear programing model optimized the allocation of Naval ship construction contracts to private shipyards.

The objective function, cost, was based on factor analysis of the labor and equipment resources of each of the private yards. The primary difference in labor cost among yards was assumed to be the difference in regional wage rates. The problem of labor productivity was not directly addressed; it was stated that "differences in labor productivity, if any, could not be measured."² Labor productivity was assumed to be dependent upon the facilities of a yard. Labor productivity, using alternative facilities, was estimated and applied to hull construction, electrical outfitting, and other outfitting in the

¹Beazer, W. F., et al., "An Economic Analysis of the U. S. Shipbuilding Industry for the 1970s," Vols. I and II, Report R-159, Institute for Defense Analyses, Arlington, Virginia, July 1969.

²Ibid., Vol. I, p. 21.

proportion historically found for each of several broad categories of ships. Adjustments were made for other factors such as learning.

For repair and overhaul none of these procedures is relevant: productivity of different facilities in repair work is unknown because of lack of productivity measures. Learning applies only to repetitive processes, but repair and overhaul jobs are varied and repeat only infrequently.

Consequently, no reliable distinction among yards can be made on the issue of overhaul or repair productivity. Since such distinction is crucial to an LP model, such modeling also strikes out as a candidate for evaluation of shipyard utility.

3. Total Cost Comparison

As it became clear that the two above models--simulation and linear programming--require a measure of productivity, the study focus was shifted to a model which assumes that productivity is invariant. A comparison of total ship repair or overhaul costs between the individual Naval shipyards might provide a ranking of shipyards solely on the basis of total costs for comparable work.

a. Comparison of Private and Naval Shipyards

An example of a total cost model is contained in a study by Arthur Anderson & Company.¹ Although the Arthur Andersen study was directed to comparing private and Naval shipyards, and while this investigation is directed to comparing

¹"Report on Survey and Analysis of Differences Between U. S. Navy Shipbuilding Costs at Naval and Private Shipyards, Shipbuilding Cost Study," Arthur Andersen & Company, Chicago, Illinois, 30 November 1962.

among Naval shipyards, an examination of the study was undertaken for the purpose of gaining insight into a total cost model.

Arthur Andersen made detailed cost comparisons between Naval and private shipyards for construction, conversion, alteration, and repair work. The study group analyzed the work accomplished in Naval and private shipyards for each ship type and computed the adjusted contract cost or price for the various categories of work. Considerable effort was spent in trying to establish the physical comparability of work prior to comparison of costs.

The study concluded that new construction costs to DoD at private shipyards were 16% less than at Naval shipyards, conversion costs were 1.2% less, repair costs were 3.4% less, and that there were no significant differences in alteration costs.¹

By far the largest dollar comparisons were performed on new construction. Overhauls of combatant ships were not considered (only a few combatant ships, primarily nuclear-powered, are overhauled in private shipyards), thus eliminating the major overhaul expenditure item from comparison. Similarly, alterations of combatant ships were not considered. In all, an extremely large part of the normal type of work performed by a Naval shipyard was eliminated from comparison. A summary of the comparisons, by shipwork category, is shown in Table 2.

¹NAVSHIPSYSCOM has recently contracted for a study which will attempt to redetermine the cost differences. The study report is due May 10, 1972. The Shipbuilders Council of America has contracted with Ernst and Ernst, an accounting firm, for a similar study to compare cost differences between private and Naval shipyards.

Table 2

Arthur Andersen & Co. Study

Comparisons of Private vs. Navy Shipyards

Shipwork Category	Total 1960-1962 Program ^{a/}		Scope of Study			
	Millions of Dollars	% of Total (10,329)	Millions of Dollars	% of Category	% of Program (10,329)	% of Study (1,964)
Construction	7,698	74.5	1,630	21.1	15.7	83.1
Conversion	1,643	15.9	317	19.1	3.1	16.1
Regular Overhaul	690 ^{b/}	6.7	13 ^{c/}	1.9	0.1	0.6
Alterations	298 ^{b/}	2.9	4 ^{c/}	1.3	0.0	0.2
Total	\$10,329	100.0	\$1,964	--	19.0	100.0
^{a/} Private and Naval Shipyards ^{b/} Combatants and Non-Combatants ^{c/} Non-Combatants Only						

LMI applied tests of statistical significance, using individual ship data from original work sheets,¹ to the comparisons made in the study. The results are summarized in Table 3.

¹Supplied by NAVSHIPSYSCOM.

Table 3

Tests of Statistical Significance of
Comparisons of Private vs. Naval Shipyards

Shipwork Category ^{a/}	Total Cases	Distribution of Cases by Statistical Significance			
		Confidence Levels (%)	Different	Same	Sample Size Too Small
Construction	4	2	1	1	2
		10	1	1	2
		15	2	0	2
Conversion ^{b/}	1	2	0	0	1
		10	0	0	1
		15	0	0	1
Regular Overhaul	10	2	3	7	0
		10	4	6	0
		15	5	5	0
Alterations	28	2	2	15	11
		10	4	13	11
		15	5	12	11

^{a/} As in Table 1.

^{b/} No statistical test possible because data were not available on spread of costs.

While the Arthur Andersen study concluded that substantial construction cost differences existed between Naval and private shipyards, only in one out of four comparisons could this conclusion be substantiated statistically at a 10% confidence level. In two cases the sample size was too small to be conclusive. Only one comparison (case) of ship conversion was presented, and the available data were insufficient for statistical testing.

In the area of more interest to this investigation, only four out of ten regular overhaul cases provided statistically significant cost differences. The Arthur Andersen conclusion with respect to ship alteration costs (no difference) was confirmed by statistical test.

While statistically significant differences were found in one case of new construction and several cases of parts of overhauls of noncombatants, the statement that private shipyards are less costly than Naval shipyards cannot be made with assurance. NAVSHIPSYSCOM (then Bureau of Ships) found in a review of the Arthur Andersen study that "the consultant experienced great difficulty in developing samples of comparable work and, in the ship repair area, was unable to do so at all."

The Arthur Andersen study represented a very substantial effort and surveyed the costs of all work performed on Navy ships in Naval and private shipyards. Nevertheless, their conclusions were necessarily constrained to an extremely small portion of overhaul and repair work because of inability to find enough comparable work packages. The experience of that study illustrates the obstacles in attempting to use the total cost approach, even in the area of new construction.

b. Comparison of Overhaul Costs Among Naval Shipyards

The obstacles faced by Arthur Andersen in their study led LMI to examine more deeply the possibility of defining comparable repair work packages within the Navy shipyard complex that could be used in a total cost model.

It is commonly assumed, outside the ship-operating and ship-maintenance community, that the cost of an overhaul is

not highly variable. It is a poor assumption. The average cost of repair of the 23 destroyers overhauled in FY 1970 was \$1.5M,¹ including Appropriation Purchases Account (APA) material. The range was from \$0.9M to \$3.2M, with a large coefficient of variation of 37%.² This variation indicates the magnitude of the uncertainty which prevents valid comparisons of one yard with another. While a number of factors contribute to this variation, the relative contribution of each factor to the total variation cannot be determined.

One factor is the amount of industrial work done on Navy ships between overhauls. Pacific destroyers receive large amounts of repair at the Naval Ship Repair Facilities in WESTPAC. No such facilities are available to Atlantic destroyers. This may result in generally better destroyer condition upon entering overhaul in the Pacific shipyards, and may explain why the average cost of a Pacific destroyer overhaul is lower than an Atlantic overhaul.

Another factor is the widely different amounts of steaming among ships during the period between overhauls. For example, during the period FY 1966 through FY 1969, the fuel consumed by a destroyer, averaged over the period between overhauls, varied among 109 destroyers from 3,800 to 11,700 gallons per day. Such differences in intensity of use intuitively indicate that ships enter overhaul in widely varying condition. Variations also result from differences in environment, quality of the crew (both operators and maintainers), and the emphasis placed upon shipboard maintenance.

¹The cost of the overhauls, including alterations, was \$1.8M, average.

²Coefficient of variation is the ratio of one standard deviation to the average.

The problem of identifying comparable repair work packages to the precision required to discriminate among the Naval shipyards appears insurmountable; the inherent variation in repair work is too great to ignore the differences. Therefore, a total cost model is considered not applicable to the question of shipyard utility.

4. Fixed Cost Comparison

The last model LMI investigated also assumes invariant productivity. It is based on a Navy study conducted in 1964.¹

As a part of the study, each Naval shipyard was directed to estimate what its total overhead and direct labor expense would have been if its workload during FY 1963 had been 50%, 75%, 125%, and 150% of actual workload. A linear extrapolation of those points to a zero workload level indicated an average annual fixed overhead expense of \$14.4 million per yard. The shipyards were ranked on the basis of fixed cost savings that could be realized from their closure. The New York Naval Shipyard was closed in 1965 and the closing of the Portsmouth Naval Shipyard was projected for 1974.

a. Historical Trends in Overhead Costs

In industrial cost accounting, depreciation, property taxes, insurance, and interest on borrowed capital are the only costs which are fixed in the sense that they do not vary at all with changes in the volume of plant activity. There are other costs, called semi-fixed or semi-variable, which have some more or less fixed components over short periods of time. Some examples of semi-fixed costs include senior

¹"Study of Naval Requirements for Shipyard Capacity," Shipyard Policy Board, 1964. (Confidential)

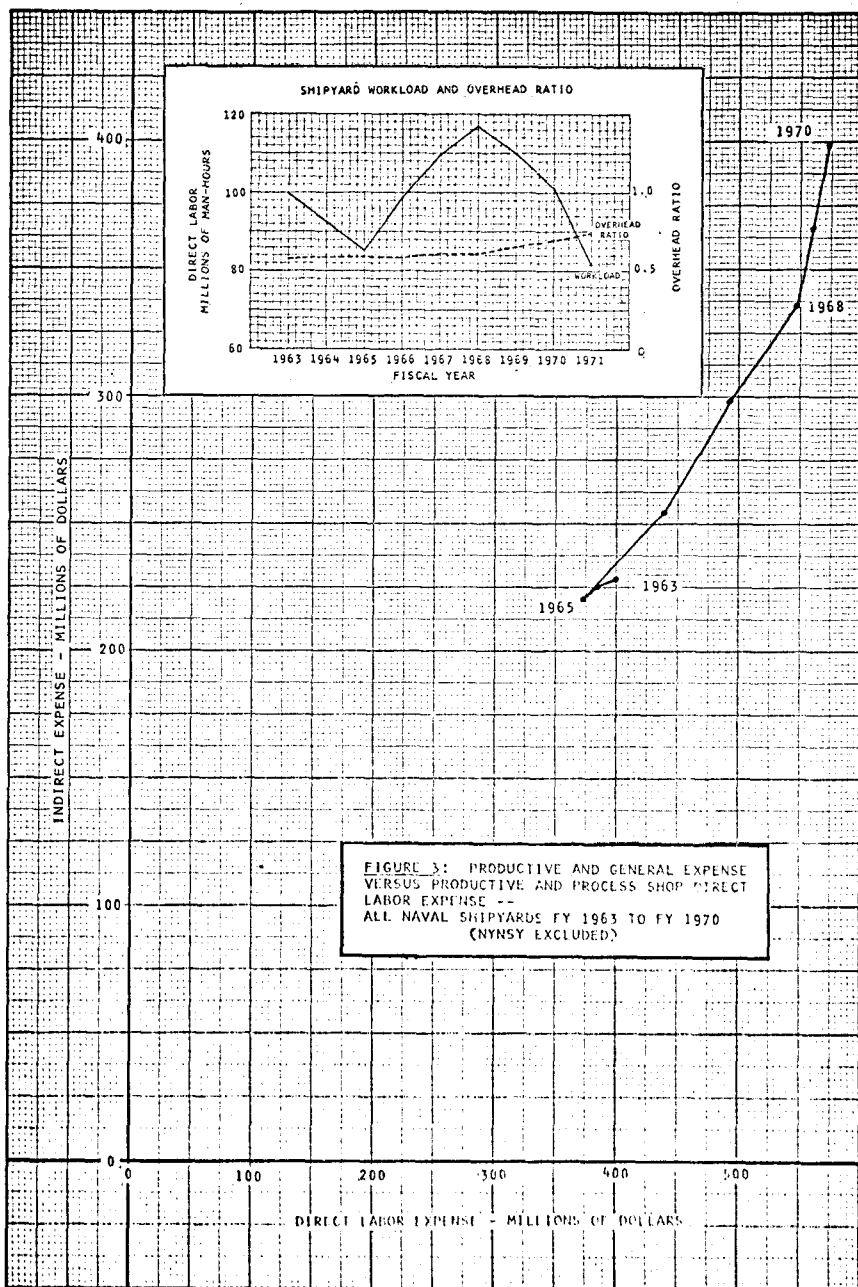
management salaries, payroll processing and building maintenance. All of these are overhead account costs.

In order to verify the fixed cost rationale used in the 1964 study, LMI investigated the historical relationship between overhead costs and yard workload in all Naval shipyards over a nine-year span. Overhead was considered in two classes, corresponding to the accounting breakdown used in the Naval shipyards. The first class was the overhead of the productive work centers, which corresponds to manufacturing overhead in industrial practice. The second class includes the expenses of the general cost centers, which are applied to both process shops and productive work centers. That class corresponds to general and administrative expense in industrial practice.

The relationship between overhead and direct labor over the period FY 1963 to FY 1970 for all Naval shipyards combined is given in Figure 3.¹ The periods 1963 to 1965 and 1968 to 1970 were periods of declining workload, whereas 1965 to 1968 was a period of expanding workload.

The periods of declining workload do not show a consistent change in overhead costs. The periods of declining workload are believed to reflect a variety of effects such as increases in overhead work, pay increases for graded personnel, and the yard managers' reluctance to reduce the work force. The net effect is that overhead reduction lags direct workload reduction. In an expanding workload period it might be expected that overhead would lag growth in workload. Yet, Figure 3 indicates that in an expanding workload period (FY 1965 to FY 1968)

¹The relationship for individual yards is given in Appendix B.



overhead increase is nearly proportional to the increase in direct workload. This may be attributed to causes such as accomplishment of deferred maintenance and increased training required by projected further increases in work force.

Nevertheless, it should be expected that overhead costs will not increase proportionately with the increase in direct workload. When overhead costs do increase proportionately, the conclusion may be reached that overhead is being managed to achieve some target overhead rate.

Total cost management and control is the essence of the managerial function. Yet habit, tradition, or the dictates of a man-made accounting system make it convenient, or compulsory, to classify costs as either direct or overhead. This practice only clouds the real issue. It confuses and frustrates. It bewilders rather than clarifies. It divides management resources and often focuses a disproportionate amount of attention on one segment--to the detriment of the total. A relatively low overhead rate is often acclaimed as evidence of management excellence--without any consideration for total cost performance. To strive for a predetermined overhead rate or ratio is not only unrealistic, it is also confounding, capricious, and costly. It is a defeatist approach¹ which is often taken to avoid trouble or frustration.

It appears to LMI that the shipyards are managed to achieve some accepted overhead rate. The conclusion was confirmed informally with persons familiar with shipyard management practices. A major reason for such management is that shipyard managers do not have productivity or other standards by which

¹Phillips, E. W., "Overhead--Burden or Benefactor," The Internal Auditor, March-April, 1968, p. 55.

to evaluate performance. As a consequence, management attention is directed to what appears to be manageable--the overhead rate.¹ If so, estimates of fixed cost, based upon overhead analysis, are invalid.

b. Historical Trends Before and After Closing a Shipyard

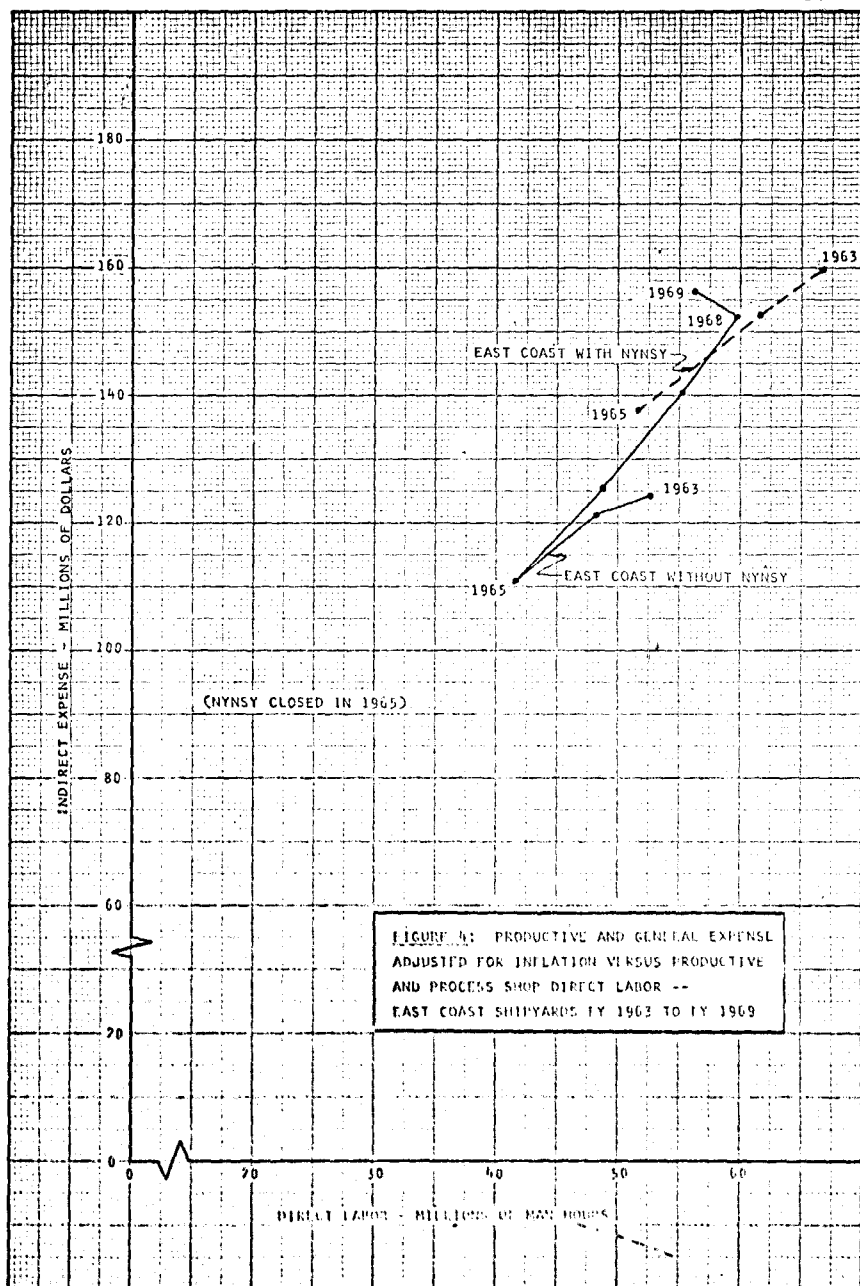
The closing of New York Naval Shipyard (NYNSY) offered a chance to examine actual costs and savings realized through a reduction in the number of shipyards.

Figure 4 shows overhead cost against direct workload for the East Coast Naval shipyards, both with and without NYNSY, for the period FY 1963 to FY 1969. The data have been adjusted for inflation.² If fixed cost savings were realized as a result of closing NYNSY, the two curves of Figure 4 would be displaced by the amount of the savings. However, the graph shows that over the range of man-hours when the combined direct workload of the yards, less NYNSY, equaled the level of the yards with NYNSY (between 52 and 60 million man-hours), the overhead cost difference was between a \$5.0M saving and a \$3.0M loss.

The individual yard cost comparisons (in Appendix B) were also examined for this expansion period. Linear extrapolation through the 1965 and 1968 points for each yard also results in wide variation of the intercept on the overhead

¹Long Beach Naval Shipyard appears to be an exception. See Appendix B, Figure B-6.

²The base year for adjusting inflation was 1965. Direct labor cost data were not available for NYNSY. Therefore, direct man-hours were used in the abscissa of Figure 4 in lieu of direct labor dollars as used in Figure 3.



cost axis, ranging from a negative \$4M to a positive \$11M. Such variation, especially the above to below zero intercepts, demonstrates how uncertain fixed cost estimates are, and strongly suggests that linear extrapolation beyond the range of the actual data is misleading.

c. Comparison of 1964 Shipyard Policy Board Study with Actual Costs

A further evaluation of the fixed cost approach may be obtained by comparison of the 1964 Shipboard Policy Board estimates of annual savings and closing costs with actuals as subsequently estimated by NAVSHIPSYSCOM.

(1) Annual Savings

The 1964 study estimated the maximum and minimum savings to be obtained through closure of NYNSY in the following manner:

<u>Annual Savings</u>	I (Maximum)	II (Minimum)
Due to transfer of new construction to private yards	\$ 9.8M	\$ --
Due to savings in overhead	6.1M	11.5M
Rehabilitation and modernization of equipment	0.7M	0.7M
Military support	0.6M	--
Military personnel	<u>0.9M</u>	<u>0.9M</u>
	\$18.1M	\$13.1M

The largest single saving, \$9.8M, was based on transferring new construction workload from NYNSY to private yards. However, since the saving was based upon the assumption that private yards are less costly, it could have been obtained by transferring the work to private yards even if NYNSY had stayed

open. Therefore, the saving should not have been credited to the closure of NYNSY.

The maximum and minimum cost estimates were obtained in two separate analyses. For that reason the savings in overhead figures appear to be interchanged, but were stated as shown. The \$6.1M estimate of savings, through transfer of work to the Philadelphia and Boston Naval Shipyards, was based upon a forecast of improvement in the overhead to direct labor ratio from 49% to 44% at Philadelphia. The data for Philadelphia (Figure B-3, Appendix B) show no such result in the actual overhead with increased direct workload. A similar, although not as clear-cut, result is obtained for Boston NSY (see Appendix B, Figure B-2). The \$11.5 estimate was obtained from the shipyard data by linear extrapolation of total overhead and direct labor expenses to the zero workload level, as described earlier on page 23.

The saving due to rehabilitation and modernization appears to be partly independent of NYNSY closure. If the work at NYNSY had been transferred to another Naval shipyard, it seems logical to assume that the facilities at the latter yard would have been worked harder, thus requiring more rehabilitation or maintenance and, perhaps, modernization. Moreover, the \$0.7M annual saving shown represented less than 2% of the \$46.2M short-range investment in facilities for Naval Shipyards in FY 1966.¹ The estimated \$.7M loses significance when compared to the variation in facilities investment over the next two years (a \$28M range).

¹"Status of Shipyards," Hearings by the Seapower Subcommittee, House of Representatives, 91st Congress, p. 10583, 1970.

The military support item represents non-industrial functions to be transferred to other activities, with an expected saving due to reduced fixed overhead. The reason for its omission in Column II cannot be determined but there is no known basis for an assumption that those costs would disappear.

Whether the military personnel item represents a true saving depends upon whether the number of officers in the Navy was correspondingly reduced. LMI accepts the study assumption that it was a true saving.

Following the arguments given above, the Policy Board Study would have predicted the minimum savings as:

Annual Savings

Due to savings to overhead	\$6.1M
Rehabilitation and modernization of equipment	-0-
Military support	-0-
Military personnel	<u>0.9M</u>
	\$7.0M

LMI's analysis of the history of the East Coast yards indicates the saving in overhead was no more than \$5.0M under the conditions prevailing after the closure of NYNSY. Therefore, total saving may not have exceeded \$5.9M per year (\$5.0M overhead saving plus \$0.9M military personnel saving). In fact, a loss of \$2.1M per year (\$3.0M loss (page 26) minus \$0.9M military personnel saving) could have occurred.

NAVSHIPSYSCOM performed an internal study to attempt to identify the actual savings realized through

closing the NYNSY.¹ The savings identified by that study were based on averages of costs incurred during FY 1963 and FY 1964, a period of declining workload. The principal items were \$14.1M for salaries, \$6.1M for maintenance, and \$1.3M for power plant operation. No offsets are included for corresponding increases in other yards; therefore, a comprehensive evaluation of the actual savings was not accomplished. The range among estimates and actuals (\$2.1M loss to \$18.1M saving) suggests the uncertainty of fixed cost estimates.

(2) Closing Costs

Closing costs estimated by the 1964 Shipyard Policy Board were as follows:

<u>Costs</u>	<u>I</u> <u>(Maximum)</u>	<u>II</u> <u>(Minimum)</u>
Moving costs of employees transferred	\$ 6.1M	\$ 4.3M
Shipment of residual inventories	4.2M	1.2M
Cost to preserve facilities	<u>3.2M</u>	<u>2.4M</u>
Subtotal	\$13.5M	\$ 7.9M
Tenants and satellite support	\$ 0.3M	\$ 0.2M
Buildup of special capabilities	3.2M	3.2M
Added cost of completing current work	5.8M	2.3M
Added cost of incomplete work transferred	<u>1.8M</u>	<u>0.9M</u>
Total	\$24.6M	\$14.5M

NAVSHIPSYSCOM also attempted to identify actual closing costs.² They collected costs of the first three items listed above plus others not considered in the 1964 study.

¹Memorandum for File 0731:AVP:mh, Serial 151, 5 March 1970.

²Ibid.

NAVSHIPSYSCOM ascribed actual closing costs of \$20.6M to the three items, in contrast to the subtotals shown above (\$13.5M to \$7.9M). The last four items listed above were not examined in the NAVSHIP study but may well have incurred a similar growth. It appears to LMI that the true costs of closing NYNSY may have been as much as \$37M.¹ At a saving of \$5.9M per year and a 10% discount rate this implies a period of 10 years before break-even.

d. Summary of Fixed Costs

Fixed costs are difficult to quantify. In any event, they appear to be small. For example, the potential saving obtained by the closing of a shipyard is less than 1% of the annual operating budget of the Naval shipyards. Therefore, the fixed cost model is not a candidate for evaluating Naval shipyards.

5. Summary of Model Investigation

Four candidate models were investigated for their applicability in analysis of shipyard utility.

- Simulation
- Linear Programing
- Total Cost Comparison
- Fixed Cost Comparison

¹The average of the maximum and minimum subtotal is \$10.7M so that cost growth was about 92% (20.6 vs. 10.7). The average of the maximum and minimum grand total is \$19.5M. A 92% cost growth would be about \$37M.

Both the simulation and the linear programming models are not applicable because they require a measure of shipyard productivity or efficiency. Such a measure does not exist. Those studies specifically addressing productivity--even though the results were in conflict--described only new construction of noncombatant ships and are not applicable to overhaul and repair work.

The total cost comparison, a model that has been used to compare Naval shipyards with private shipyards, does not demonstrate cost differences with adequate statistical certainty. Wide variations in the condition of ships entering overhaul, and a lack of ability to measure differences in ship condition, preclude the identification of comparable overhaul and repair packages. For these reasons the total cost model is inappropriate for comparison of Naval shipyards.

The fixed cost model is even less representative of the real world than the other three. There is so much uncertainty in the definition and measurement of fixed cost in the Naval shipyard complex that its use in evaluating the utility of Naval shipyards is not appropriate.

LMI cannot identify a model at this time to evaluate the utility of Naval shipyards.

C. REVIEW OF ASSUMPTIONS

Since the search for models which characterize shipyard operations was fruitless, the assumptions made in undertaking the study were re-examined. The re-examination established

that two initial assumptions are not true. Those are:

- Cost minimization of shipyard operations alone can be an objective.
- Shipyard productivity is measurable.

1. Cost Minimization as an Objective

An assumption implied by the task order is that cost minimization of shipyard operations alone can be an objective. The primary mission of the Naval shipyards has always been to provide the required level of service to the fleet. The shipyard complex must function under a number of constraints, such as homeport policies, overhaul cycles, shipwork priorities, level of repair approved, and governmental management policy. These constraints are real, and in varying degrees, work in opposition to the goal of cutting costs. Yet, given the constraints, shipyard management must, and does, attempt to minimize cost. Lacking a measure of performance, such as profit, however, there is no real indication of how well they are doing, even in comparison with other Naval shipyards. They all may be excellent or they all may be bad.

Given the constraints that exist because the Naval shipyard complex is an element of the DoD rather than a private venture, the shipyard complex should not be looked upon in isolation. Rather, it should be evaluated on its primary mission, just as a carrier strike force should be evaluated on its capability in a combat role. Cost minimization in the shipyard complex must be sought with a broader goal in mind--its impact upon fleet military capability.

Cost reduction in the shipyards, achieved independently of total fleet cost considerations, may adversely affect the Navy as a whole. The annual operating cost of the fleet is about \$4 billion per year, four times the annual budget of the shipyards. If an increase of 1% in shipyard efficiency is achieved, say, by reducing capacity, but causes fleet efficiency to decline 1% then there would be a net loss of \$30M per year. If cost minimization is undertaken it must be done on a level which will produce real savings.

2. Shipyard Productivity

As discussed previously no consistent measure of productivity is available even for new construction. Productivity comparison among Naval shipyards is even more difficult since a Naval shipyard's primary workload is repair and overhaul work, which is much harder to measure.

While it might be expected that a job such as "repair a main feedwater pump" involves the same amount of work in each Naval shipyard, one need only consider the possible differences that may be encountered in execution of the job to see the difficulty. One shipyard may elect to disassemble and repair the pump in its location in the ship, another may find that an access opening for some other equipment has been cut and that it is better to remove the pump from its foundation and move it to the shop. The cost of repair of the pump in the second case--where the repair was done in the shop--may be much lower but the access opening costs and the rigger and crane operating costs should also be considered. Repair-in-place may be essential--at correspondingly high cost--because of limited access to a compartment. This is not to suggest that job costs cannot be compared, but that the comparison is intricate and the methods and related

activities must be considered in every case. Such intricate considerations are most often subjective and, because the internal arrangements vary even among ships of the same class, a true comparison of job costs would require very detailed work analysis.

If there were enough ships and similar installations of equipments, it would be practicable to engineer standards for each method of repair and to compare the costs of accomplishment. While some repair and overhaul work is quite straightforward, such as cleaning and painting of anchor chain, most work does not lend itself to engineered standards. LMI believes that the cost of developing such standards, considering the small numbers of similar ships and the infrequency of identical repair, cannot be justified by cost savings. While engineered job standards, if they covered a substantial part of the work, would provide some measure of productivity of Naval shipyards, it appears that they are out of reach.

Another approach to evaluating shipyard productivity would be to determine each shipyard's contribution to the condition, or readiness, of the fleet. Essential to this approach is a means of measuring ship condition that can assign a number on a continuous scale to each ship. There appears to be no practicable way to do that, either through physical measurement or through subjective assignments of numbers, or some combination of the two.

An alternative to direct measurement of ship condition, would be to set standards of ship condition when the ship leaves overhaul. Comparison of numbers of overhauls of the same ship type could be used to evaluate shipyard productivity, assuming

identical deterioration since the previous overhaul. The ship condition standards may be either formally documented or the subjective opinion of experienced ship maintenance and operating personnel. The form of evaluation in this case would be a go/no-go statement. Formal standards could be developed as part of new ship acquisition programs at acceptable costs where a number of identical ships are procured. The standards would be used to fix ship condition at one point in time.

Refined estimates of shipyard productivity also could be obtained through assembly of data from several overhaul cycles of similar ships. The data would include such items as overhaul resource investment, time between overhaul, fuel consumed between overhaul, maintenance applied between overhauls and other quantifiable intervening variables. Those data would be used to better define the ship condition entering overhaul. With estimates of the change in ship condition produced during overhaul the accompanying resource investment could be analyzed with more confidence. This method would be less costly, but also less exact, than if job standards or a continuous scale productivity measure were available. Therefore, it could only be used as a check on other methods for improving shipyard productivity, not for making facility decisions.

Even if it is not desired to estimate ship condition or measure shipyard productivity, it is essential that the quality control of ships leaving overhaul be objective. By assigning that responsibility to a fleet organization, quality control will rest with those most affected by ship condition and budget. The fleet organization must be staffed with appropriate expertise and continuity of personnel.

The above discussion on engineered job standards and ship condition measurement is not meant to imply that shipyard

productivity cannot be upgraded in their absence. Shipyard performance can be upgraded through the application of industrial engineering to improve material flow, through more detailed pre-job site surveys, through improved material and work force scheduling to reduce lost time, through changes in personnel classification and training to reduce trade emphasis and to emphasize accomplishment of complete jobs, and through intensive and continuing review of management practices, both at the NAVSHIPSYSCOM and shipyard level, to identify more meaningful indices of performance and to emphasize active involvement at the local level in improving shipyard performance.

D. SHIPYARD ECONOMICS

The task implies that two questions need to be answered.

- How many shipyards are required?
- How should the workload be distributed among them?

It is natural to assume that the closing of any industrial operation would save money. In the shipyard case the closing costs are so large and the apparent annual savings so small and so difficult to identify as to make that assumption questionable, especially in view of the increasing uncertainty in requirements in the distant future. That means economic indifference as to the number of yards in existence.

Furthermore, it appears that workload level has little effect on the efficiency of a yard. For example, were it not that the pier and drydock space may not be adequate, all of the work on the East Coast might be performed in one yard with little change in the cost of overhauls. Because of these considerations, it should be the operating convenience of the fleet and strategic considerations that determine not only how many but which shipyards should be operated.

III. CONCLUSION AND RECOMMENDATION

The fundamental conclusion of this study is that no useful shipyard cost model can be constructed at the present time. In other words, there is no acceptable methodology for evaluating shipyard utility on the basis of economic analysis.

RECOMMENDATION: Phase II of this study not be done, i.e., do not undertake the construction of economic models for the purpose of comparing shipyards.

APPENDIX A

TASK ORDER

ASSISTANT SECRETARY OF DEFENSE
Washington, D. C.

Installations and Logistics

DATE: 13 August 1971

TASK ORDER SD-271-164
(TASK 72-8)

1. Pursuant to Articles I and III of the Department of Defense Contract SD-271 with the Logistics Management Institute, the Institute is requested to undertake the following task:

A. TITLE: Methodology for Evaluating
Naval Shipyards

B. BACKGROUND: A methodology for review of the effectiveness and cost of Naval Shipyards is required. This methodology would be used continuously to evaluate the relative utility of shipyards to the Navy. The methodology should enable a top-level decision-maker to assess the utility of each shipyard relative to its counterparts, and to see the effect of changing numbers and capacities of shipyards.

C. SCOPE OF WORK: LMI will undertake the development of a model, or a set of models to satisfy the above stated requirement. The work will be performed in two Phases:

Phase 1--This phase will include:

- 1) Identification of the various broad categories of models that may be applicable to the objective, and related supporting data bases,
- 2) Assessment of the adequacy of the existing data base and determination of feasible actions to improve the data base in terms of accuracy, precision and completeness, and
- 3) Selection of the type of model that offers the most promise of meeting the objective, considering all restraints that bear on the issue.

The product of Phase 1 shall be a report documenting LMI findings with respect to the data base and describing in general terms the type model, if any, most suited for further development.

Phase 2--During this phase the model tentatively identified in Phase 1 will be developed and tested.

The product of Phase 2 will be a report fully describing the model, defining and describing all input and output parameters and explaining the sensitivity of the methodology to each parameter or set of parameters.

2. SCHEDULE: A final report on Phase 1 will be submitted by 31 December 1971. A Phase 2 estimate cannot be established until completion of Phase 1.

APPROVED: /s/ Hugh Witt

/s/ Glenn V. Gibson

ACCEPTED: /s/ William F. Finan

DATE 16 August 1971

APPENDIX B

OVERHEAD COSTS VERSUS DIRECT LABOR
COSTS FOR THE NAVAL SHIPYARDS

APPENDIX B

OVERHEAD COSTS VERSUS DIRECT LABOR COSTS FOR THE NAVAL SHIPYARDS

In the course of the study we examined the historical trends in overhead costs as a function of direct costs (page 22). In this appendix are presented the historical trends in overhead cost as a function of direct costs for each of the nine Naval shipyards. Mare Island and Hunters Point Naval Shipyards were considered together. For comparative purposes, the trends in workload (direct man-hours expended) with time are also given on each figure.

The data shown are not directly comparable, but are adequate for our purposes. There are several reasons why they are not directly comparable. Some material costs are included in overhead, and there has been significantly less inflation in material costs over this period than there has been in labor costs. In addition, we have not analyzed the extent to which personnel upgrading may have had a greater effect on one or the other of these costs.

It may be seen that the extrapolation of the overhead trend line back through zero (on the abscissa) produces widely varying estimates of the fixed costs of the yards (at the intercept of the ordinate). In several cases the variation is due to causes such as the addition of special capability--for example, nuclear plant overhaul--and those cases must be interpreted with caution.

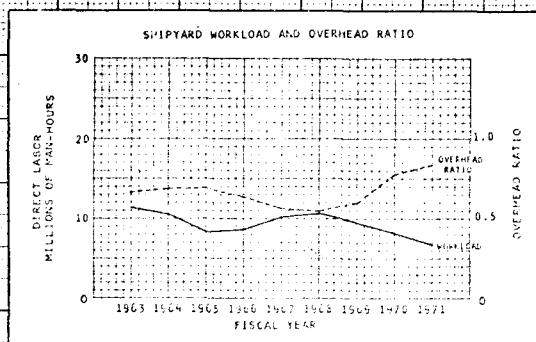
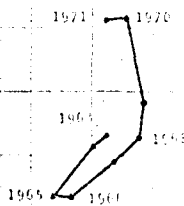


FIGURE 1: PRODUCTIVE AND GENERAL EXPENSE
VERSUS PRODUCTIVE AND PROCEEDS SHOP DIRECT
LABOR EXPENSE --
PORTSMOUTH NAVAL SHIPYARD FY 1963 TO FY 1971

INDIRECT EXPENSE - MILLIONS OF DOLLARS



DIRECT LABOR EXPENSE - MILLIONS OF DOLLARS

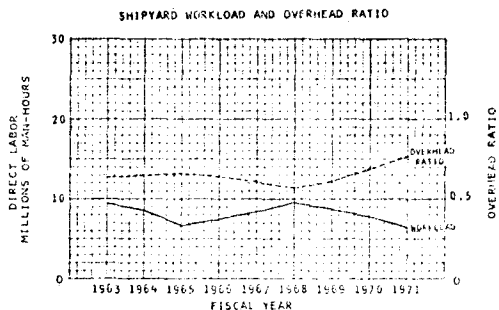
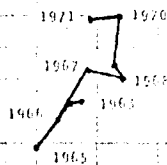
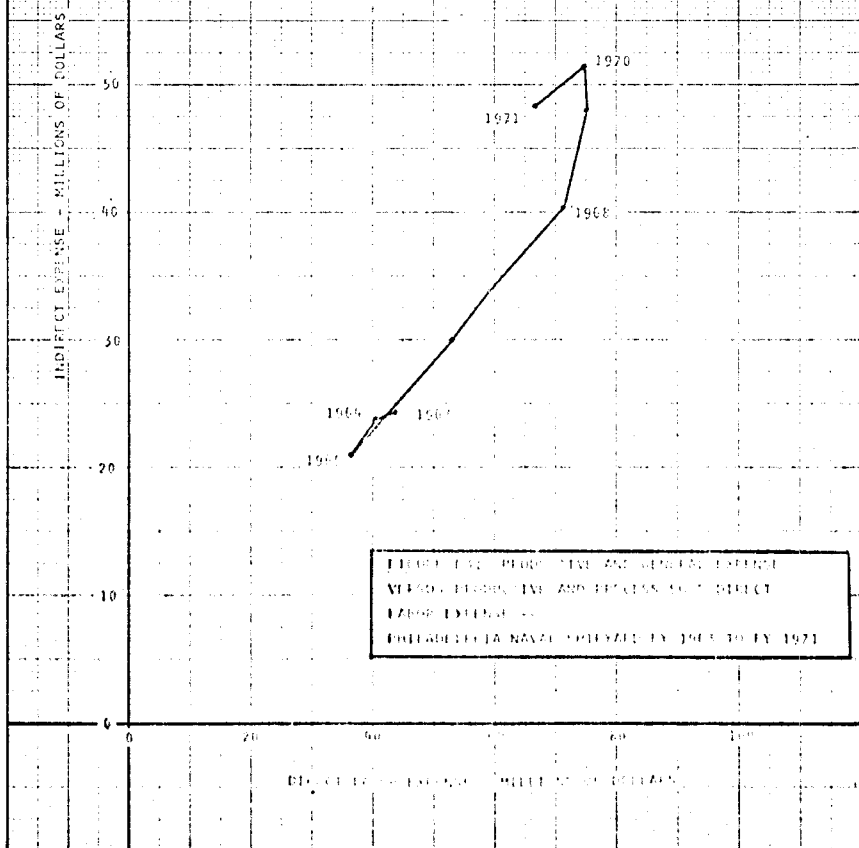
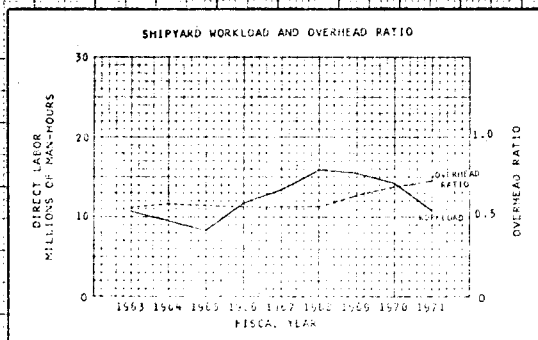


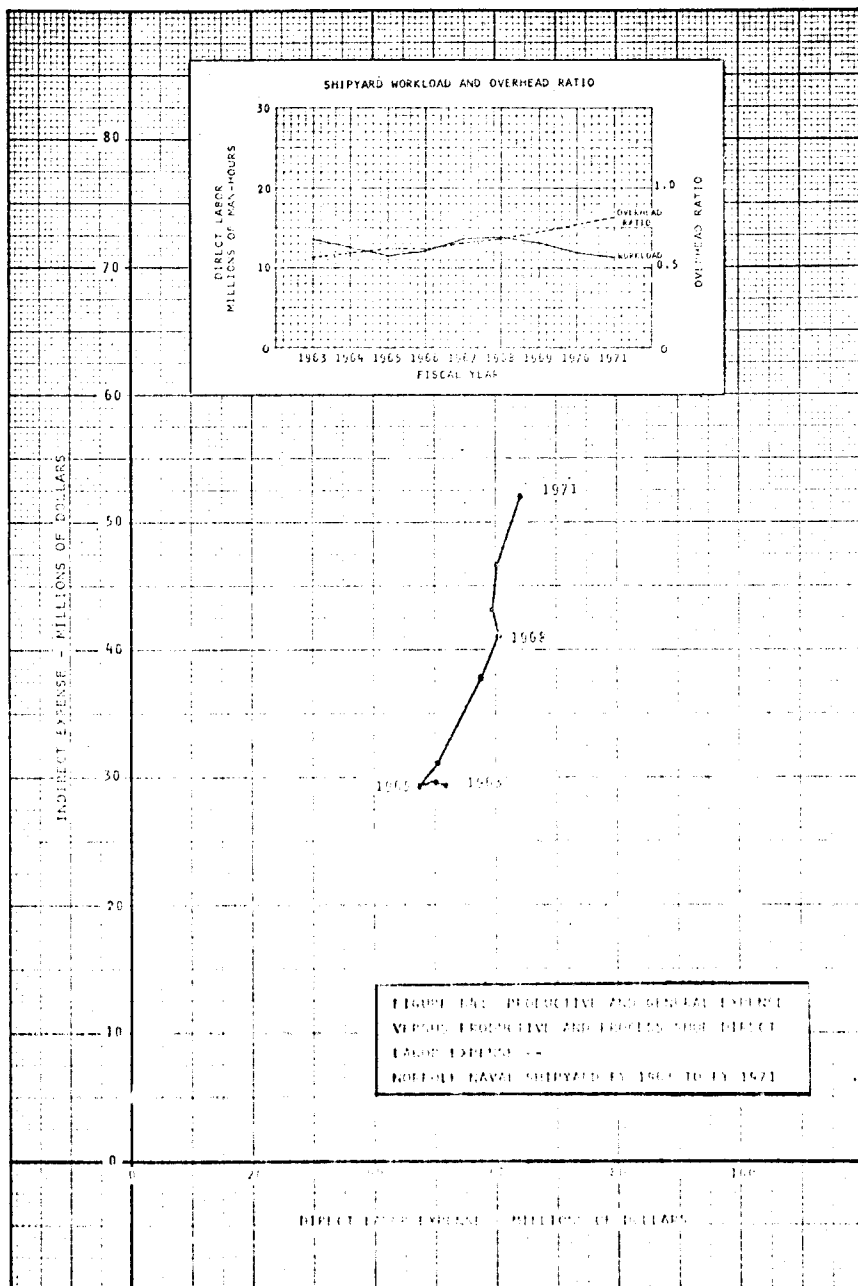
FIGURE B2: PRODUCTIVE AND GENERAL EXPENSE
VERSUS PRODUCTION AND PROCESS SHOP DIRECT
LABOR EXPENSE ---
BOSTON NAVAL SHIPYARD FY 1963 TO FY 1971

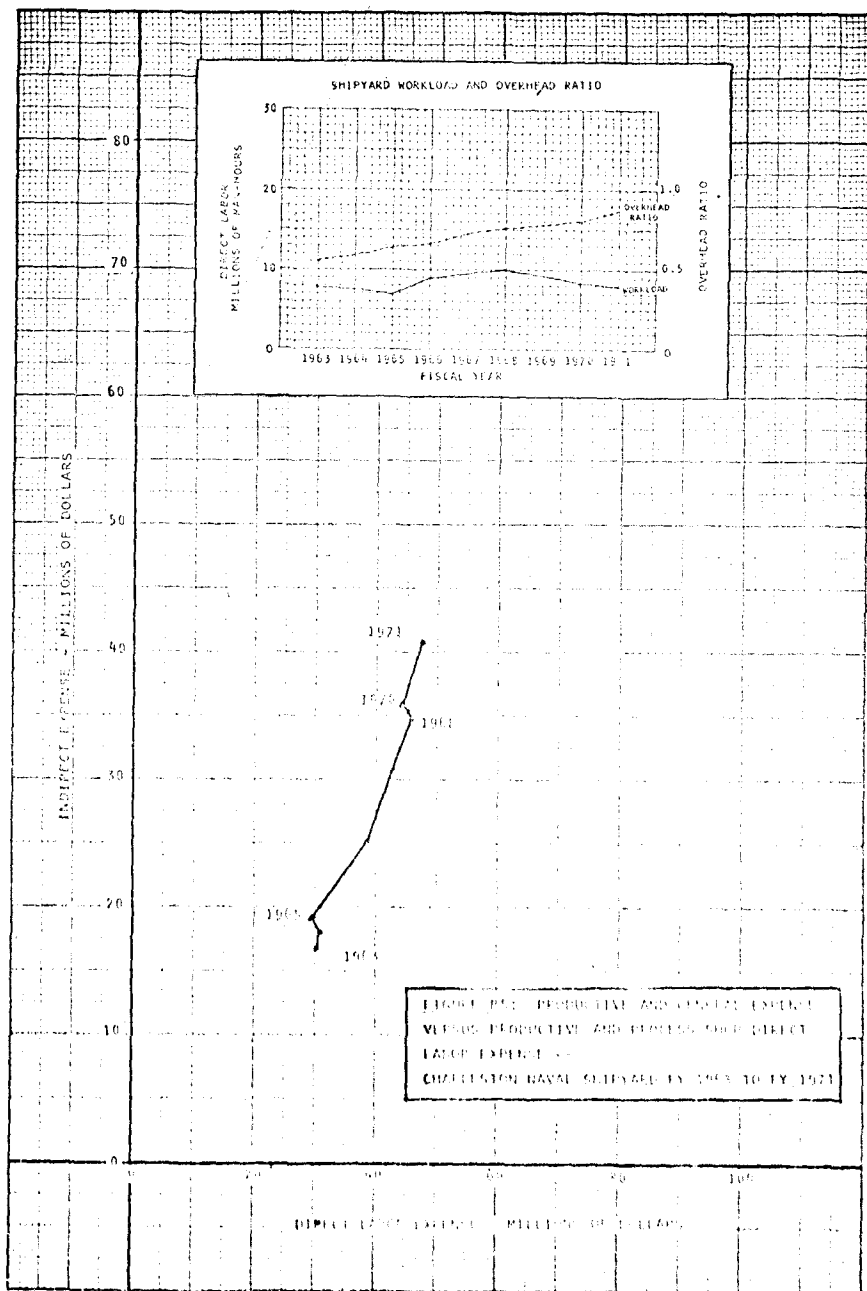
INDIRECT EXPENSE - MILLIONS OF DOLLARS

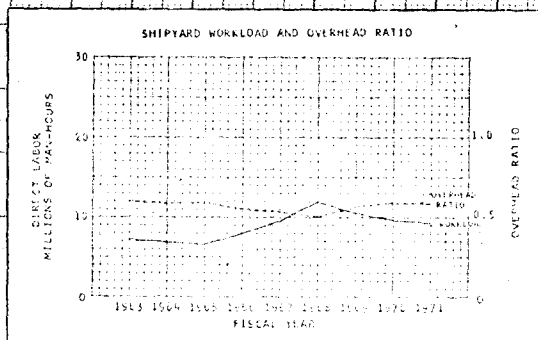


DIRECT LABOR EXPENSE - MILLIONS OF DOLLARS

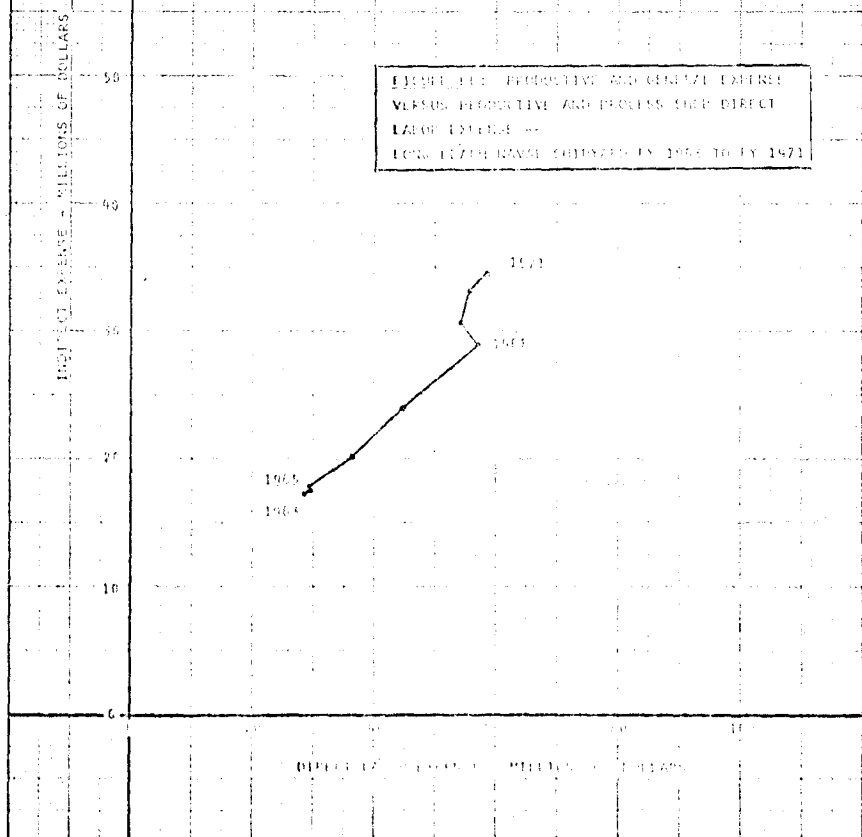


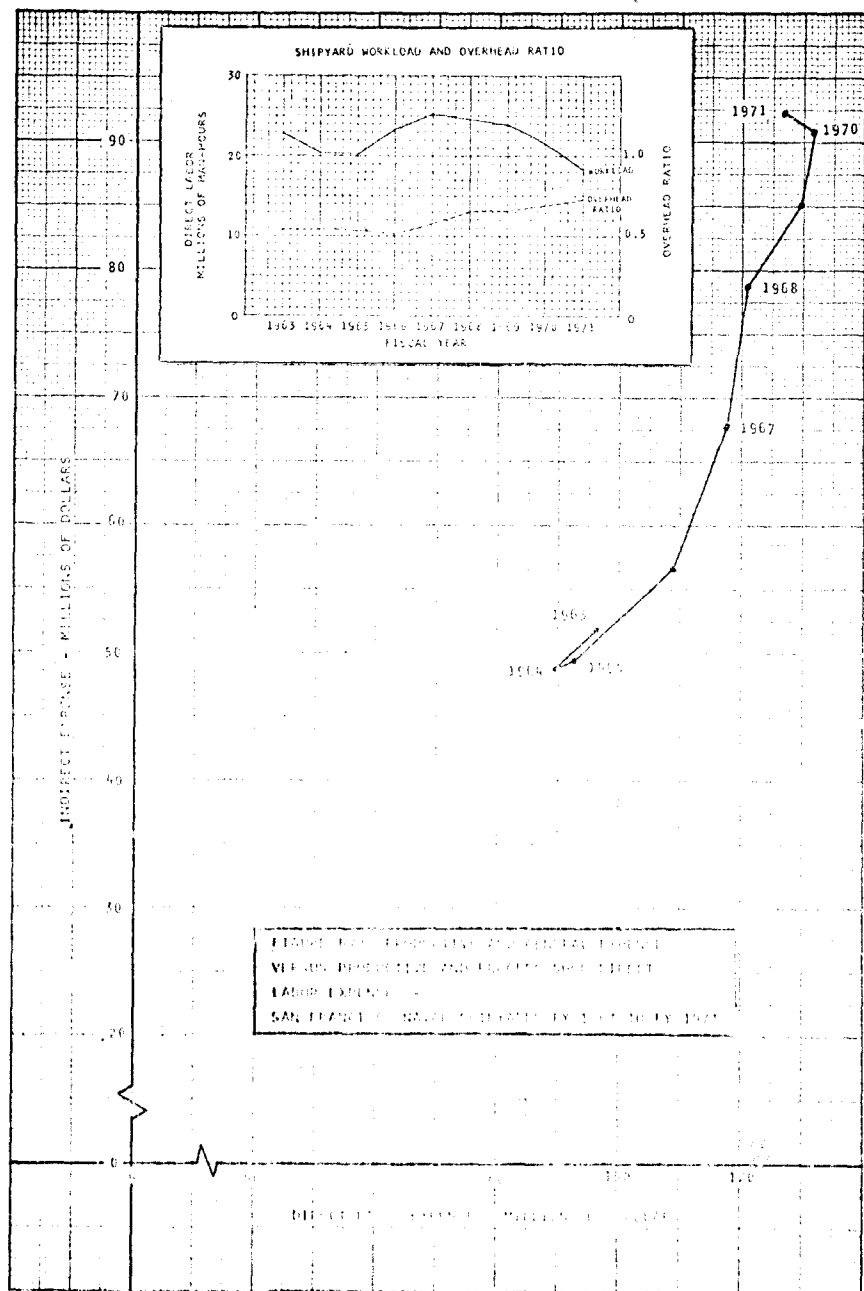


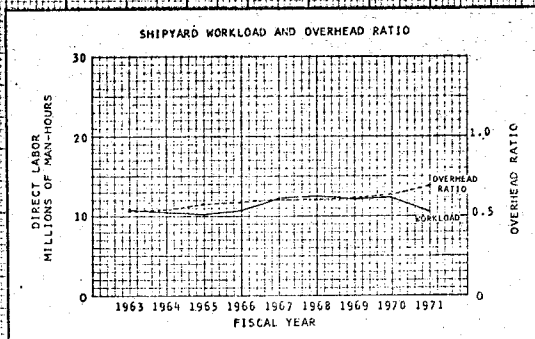




**FIGURE 111. PRODUCTIVE AND GENERAL EXPENSE
VERSUS PRODUCTIVE AND PROCESS SHIP DIRECT
LABOR EXPENSE --
LONG ISLAND NAVAL SHIPYARD, 1963 TO FY 1971**







INDIRECT EXPENSE - MILLIONS OF DOLLARS

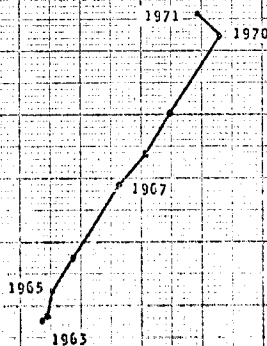
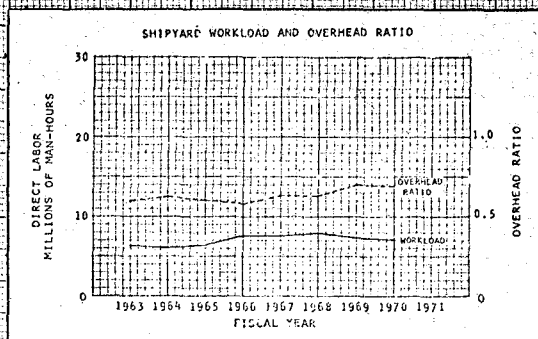


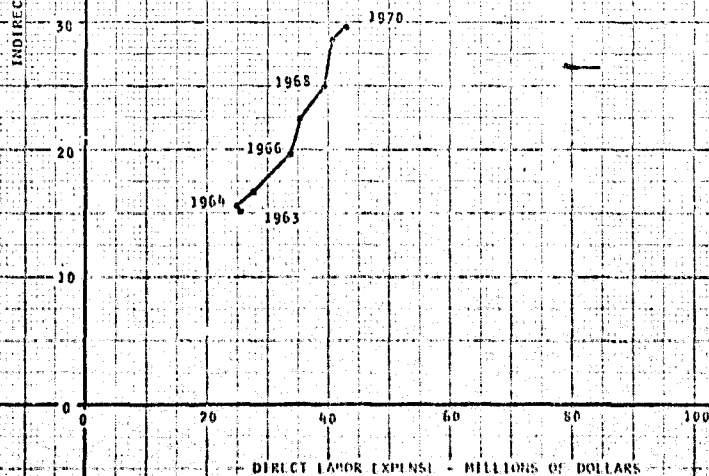
FIGURE 22: PRODUCTIVE AND GENERAL EXPENSE
VERSUS PRODUCTIVE AND PROCESS SHOP DIRECT
LABOR EXPENSE --
PUGET SOUND NAVAL SHIPYARD FY 1963 TO FY 1971

DIRECT LABOR EXPENSE - MILLIONS OF DOLLARS



INDIRECT EXPENSE - MILLIONS OF DOLLARS

FIGURE B9: PRODUCTIVE AND GENERAL EXPENSE
VERSUS PRODUCTIVE AND PROCESS SHOP DIRECT
LABOR EXPENSE --
PEARL HARBOR NAVAL SHIPYARD FY 1963 TO FY 1970



APPENDIX C

COMPARISON OF STUDIES EVALUATING
PRODUCTIVITY OF U. S. AND FOREIGN
SHIPYARDS

APPENDIX C

COMPARISON OF STUDIES EVALUATING PRODUCTIVITY OF U. S. AND FOREIGN SHIPYARDS

Two studies were found in the literature which considered shipyard productivity. One study was made by IDA in 1966;¹ another by the Webb Institute in 1969.² Both compared the productivity of private shipyards in the U. S. and selected foreign countries in the construction of commercial ships.

a. The IDA Study

This study used as its input-output measure "man-hours per delivered steel-weight ton." Steel-weight tonnage was converted from dead-weight tonnage by one equation applied both to cargo and passenger ships, and another equation for tankers. These conversion equations allowed for differences in the usage of steel between these two types of ships. The steel-weight figures were then weighted for differences in construction complexity for each of the three ship types: tankers, cargo ships, and passenger-cargo ships. The weighted figures were then divided into a two-year moving average of the product of employment and man-hours per year per employee. The IDA Study concluded that the "productivity" for the U. S. was roughly one-half that of Sweden and Japan.

b. The Webb Institute Study

This study considered the use of steel-weight tons as a measure of output but discarded it on the basis that such a measure did not allow for the differences in complexity, and

¹Williams, H., et al., "An Economic Analysis of U. S. Naval Shipbuilding Costs," Institute for Defense Analyses. Report R-120, Arlington, Virginia, December 1966.

²"Improving the Prospects for U. S. Shipbuilding," Center for Maritime Studies, Webb Institute of Naval Architecture, Glen Cove, New York, 1969.

that reliable data on man-hours for individual ships was not normally available. Webb turned instead to "value added by the manufacturer per man-hour" as their measure of productivity. The ratio of U. S. to Japanese productivity was calculated from the following ratios and estimates: a ship cost ratio of 2 to 1, labor costs as 43% (U. S.) and 28% (Japanese) of total ship costs, and a wage rate ratio of 3.9 to 1. These inputs were combined in the following equation to derive the relative productivity:

$$\left(\frac{2}{1}\right) \cdot \left(\frac{.43}{.28}\right) = \left(\frac{3.9}{1}\right) \cdot \left(\frac{1}{x}\right)$$

or x = approximately 1.3. The conclusion was that U. S. productivity was about 130% of Japanese productivity.

Since these two study results differ, we examined data on man-hours per dead-weight ton contained in the Webb Institute report. The data were converted to man-hours per steel-weight ton using the formulae contained in the IDA study. The results are summarized below:

	<u>Man-hours per steel-weight ton</u>	
	<u>U. S.</u>	<u>Japan</u>
1966 IDA	164	70
1969 Webb Institute (converted)	46	68

The Webb Institute data, as converted, indicates U. S. productivity about 3.5 times greater than the IDA results, while Japanese productivity is approximately the same in both studies. These results show the lack of general agreement on what constitutes a "good" productivity measure for ship building, even

for comparisons at the national level. As the fineness of the comparison is increased, that is, among shipyards of one nation, the comparison becomes more difficult because of problems in finding sufficient comparable data.

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and index and annotations is not to be entered on the overall report in this field)

Logistics Management Institute
4701 Sangamore Road
Washington, D. C. 20016

20. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED
21. GROUP

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Methodology for Evaluating Naval Shipyards

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13. ABSTRACT The study task was to develop a methodology for evaluating the relative utility of Naval shipyards in terms of cost and effectiveness. Phase I was a review of existing models and data, and selection of a model. Phase II was to be full-scale development and testing of the selected model. The conclusion of Phase I is that no model can be found which will satisfy the requirement. For this reason it is recommended that Phase II of the study be cancelled.

Four possible models were investigated. The first two, a scheduling-cost model and a linear programming model were rejected because an essential element, a measure of shipyard productivity, is not available. LMI does not believe the construction of a measure of productivity for detailed models is practicable for several reasons: 1) the nature of overhaul and repair work, that is, it is large and complex, and few jobs recur regularly and when they do work content varies widely, 2) the many constraints on shipyard operation, and 3) the differences among the shipyards themselves.

The third and fourth models, total cost comparison and fixed cost analysis, assume invariant productivity. The total cost model was found to discriminate inadequately between costs of new construction in private and Naval shipyards. The difficulty in finding comparable work packages in overhaul and repair work, the primary mission of Naval shipyards, suggests that that model would be even less useful.

The fixed cost analysis assumes that there are fixed costs of operating a shipyard that would be avoided by closing a yard. However, LMI can find little to support that assumption. There is no clear evidence that fixed costs are large enough to offset the costs of closing a yard. This conclusion was supported by a review of the costs of closing of the New York Naval Shipyard.

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